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16. ABSTRACT

Studies have been completed on treating a leachate from New Lyme, Ohio. The leachate was transported to Cincinnati, Ohio, where a pilot-sized rotating biological contactor (RBC) was used for a treatment evaluation.

The biomass was developed on the RBC discs with primary effluent from the City of Cincinnati's Mill reek Sewage Treatment Facility. Experiments were then conducted to determine the effectiveness of treating a hazardous waste leachate and to provide information on the following:

- o the rate of organics removal;
- o the final effluent quality;
- o the fate of priority pollutants and specific organic compounds;
- o the loss of volatiles via stripping in the RBC.

This paper reports on the results from these experiments and the applicability of an RBC to treat a hazardous waste leachate from a Superfund site.

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Biological Treatment of Leachate from a Superfund Site

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Studies were made on treating a leachate from New Lyme, Ohio. The leachate was transported to Cincinnati, where a pilot-sized rotating biological contactor (RBC) was used for a treatment evaluation. Biomass was developed on the RBC discs with primary effluent from the City of Cincinnati's Mill Creek Sewage Treatment Facility. Experiments were then conducted to determine the effectiveness of treating a hazardous waste leachate and to provide information on: the rate of organics removal; the final effluent quality; the fate of priority pollutants and specific organic compounds; and the loss of volatiles via stripping in the RBC. The results of these experiments and the applicability of an RBC to treat a hazardous waste leachate from a Superfund site are reported.

BACKGROUND

Land disposal of organic wastes is no longer regarded as an ultimate solution for solid wastes because of the potential for leachate formation and/or groundwater contamination. Leachate releases have occurred at waste disposal sites and technology is needed to remedy these conditions.

Biodegradation of the organics in leachates may provide an acceptable and cost-effective alternative for treating leachates. The rotating biological contactor (RBC) was selected as a biological treatment process to study its applicability for converting the organics in leachate into innocuous products. A pilot-sized unit was installed at the U.S. Environmental Protection Agency's Test and Evaluation Facility (T&E) in Cincinnati, Ohio to conduct such an investigation.

NEW LYME SUPERFUND SITE

The New Lyme Superfund site [*1*] was selected as the source for the leachate. New Lyme is located in Ashtabula County, Ohio approximately 40 kilometers (25 miles) north of the city of Youngstown, Ohio. The site consists of 14 to 16 hectares (35 to 40 acres) of landfill and began its operations in 1969. It operated as a combined municipal and industrial waste landfill where approximately 230,000 cubic meters (300,000 cubic yards) of wastes were disposed each year. The industrial wastes included paints, solvents, oils, coal tar distillates, and corrosive liquids. In 1978, the landfill's license was revoked and the site was subsequently placed on the National Priorities List under the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA). A remedial investigation [2] was conducted in 1983 and concluded that the soils around the site: the groundwater under the site: the sediment adjacent to the landfill, and the leachate emanating from the site had been contaminated by the landfill.

Samples were obtained from several seeps surrounding the landfill. The results showed that the leachate contained up to 2000 mg/L of dissolved organics. The leachate for the treatability study was pumped from a deep depression adjacent to the site into a tank truck and transported from New Lyme to Cincinnati for experimentation using the RBC.

PROJECT DESCRIPTION

Figure 1 shows a pilot-sized RBC that contains 1,000 m^2 (11,000 square feet) of surface area, which is roughly 10% the scale of a full-sized unit (100,000 square feet) located at EPA's T&E Facility [3]. The diameter is 3.6 m (12 ft), identical to a full-scale unit, the length is only 1 m (3.3 ft), and a full-scale unit is 7.6 m (25 ft).

The RBC was operated in a batch mode. The leachate was transferred from a storage tank to a mix tank where the volume was measured. The nutrients were then added for specific experiments. The contents were pumped into the RBC, and the RBC was operated at a constant speed of 1.5 rpm. When the reaction was complete, the contents were returned to the mix tank and then fed to the clarifier for solids removal. The overflow went to the receiving tank, where the treated leachate was stored until the analytical results showed that the material was within the allowable discharge limits.

Effluent limitations on the treated leachate were imposed by the City of Cincinnati's Mill Creek Treatment Facility (MCTF) and by laboratory prescribed contaminant levels. Both sets of limitations had to be met before the treated leachate was disposed of in the MCTF sewers. The effluent limitations set by the MCTF were as follows: total organic halides (TOX) ≤ 5 mg/L; vapor space organics (VSO) ≤ 300 ppm (4); and $6 < pH < 10$.

The internally applied limits were based on achieving a soluble gross organics level that would be equivalent to or less than a relatively high strength raw wastewater: soluble biochemical oxygen demand (SBOD) ≤ 100 mg/L;

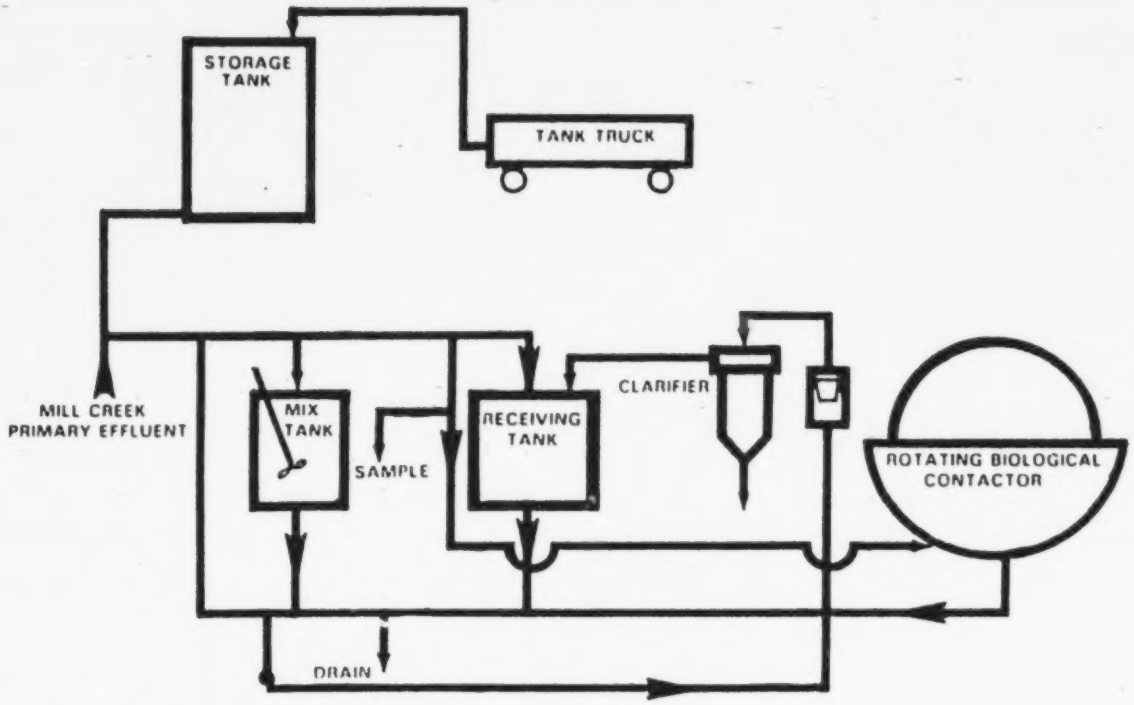

Figure 1. RBC flow schematic.

dissolved organic carbon (DOC) ≤100 mg/L; and soluble chemical oxygen demand (SCOD) ≤300 mg/L.

The underflow from the clarifier was analyzed for priority pollutants and drummed for disposal at a permitted landfill. We did experience a potentially unsafe incident with the drummed sludge. A drum bulged during storage. A gas analysis showed a high concentration of methane, which was probably caused by anaerobic degradation of the sludge. The pH of the sludge was then raised to 12 by adding caustic to deactivate the biomass. This action prevented a recurrence.

RESULTS

Experimental Conditions

The eight experiments conducted with New Lyme leachate varied in the volume of leachate fed to the RBC, the ratio of leachate to primary effluent (L/PE), the nutrient addition to the leachate, and the biomass condition (thickness, appearance, acclimation). The initial runs used a combination of leachate and primary effluent to allow for acclimation of the biomass, which was formed with primary effluent from the MCTP [5]. The initial runs also used 2800L (750 gal) instead of 3800L (1,000 gal) to conserve leachate. Nutrients were added to the leachate for experimentation to study this effect on the reaction. A fixed ratio of carbon (C)/nitrogen (N)/phosphorus (P) of 100/5/2 was used in three of the runs. These experimental variations are summarized in Table 1.

Reaction Rate

The reaction rate was determined by following the drop in the DOC with time [6]. A plot of experiments 1 and 4, are shown in Figure 2, and experiments 3 and 5 are displayed in Figure 3. Experiments 2 and 7 are shown in Figure 4. Experiment 6 is not included in the figures because its purpose was to determine the mass of volatile organics that was stripped by the RBC without any biomass. Experiment 8 is omitted because the leachate had undergone spontaneous biodegradation in the storage tank and was not representative of New Lyme leachate. The DOC at the start of experiment 8 had dropped to 280 mg/L, whereas the DOC for experiment 6 was 1780 mg/L.

TABLE 1. EXPERIMENTAL CONDITIONS

Runs	Total Vol. Gal.	Ratio Leachate/PE Gal/Gal	Nutrient Addition	Ratio C/N/P	Biomass	Comments
01	750	250/500	No	—	No Acclimation	
02	750	500/250	No	—	Poor	
03	750	500/250	Yes	100/5/2	Satisfactory	
04	750	500/250	No	—	Satisfactory	
05	1,000	1,000/0	Yes	100/5/−2	Satisfactory	
06	1,000	1,000/0	No	—	None	Volatile organics stripping run
07	1,000	1,000/0	Yes-N/No-P	100/5/0	No Acclimation	
08	1,100	1,100/0	Yes	100/5/2	No Acclimation	

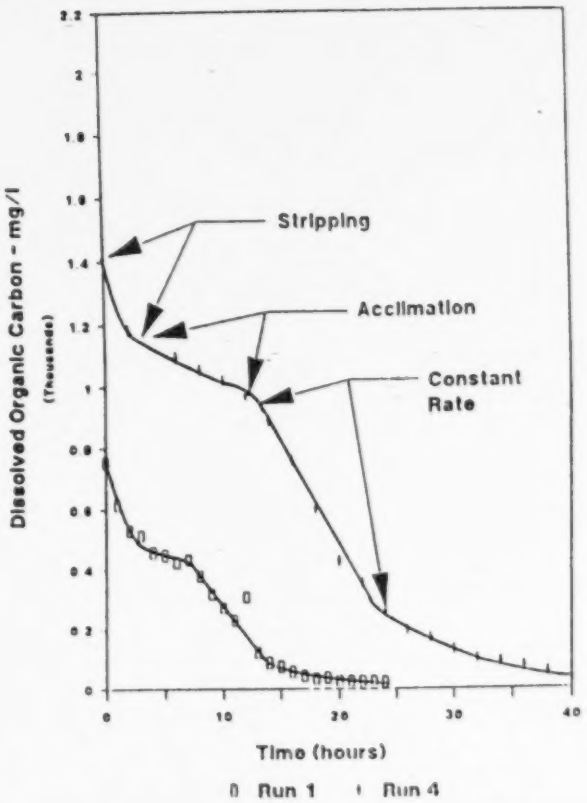

Figure 2. Disappearance of DOC with time experiment 1 and 4.

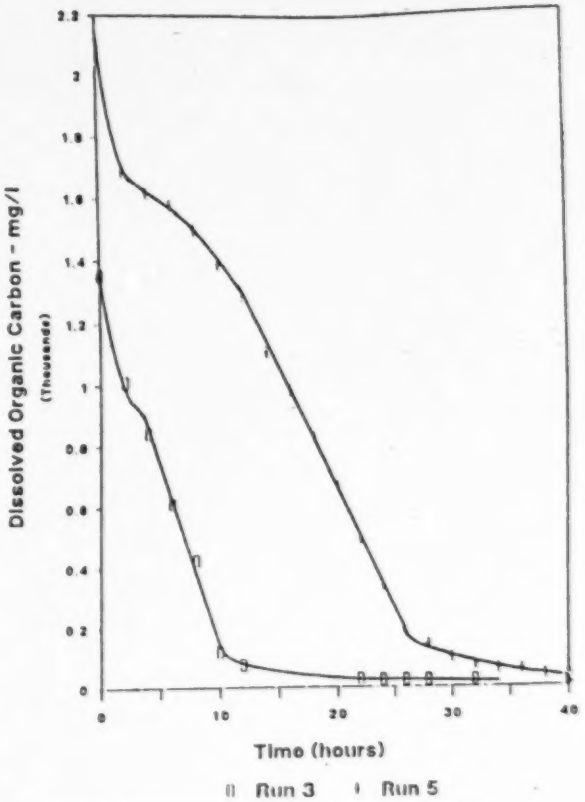

Figure 3. Disappearance of DOC with time experiment 3 and 5.

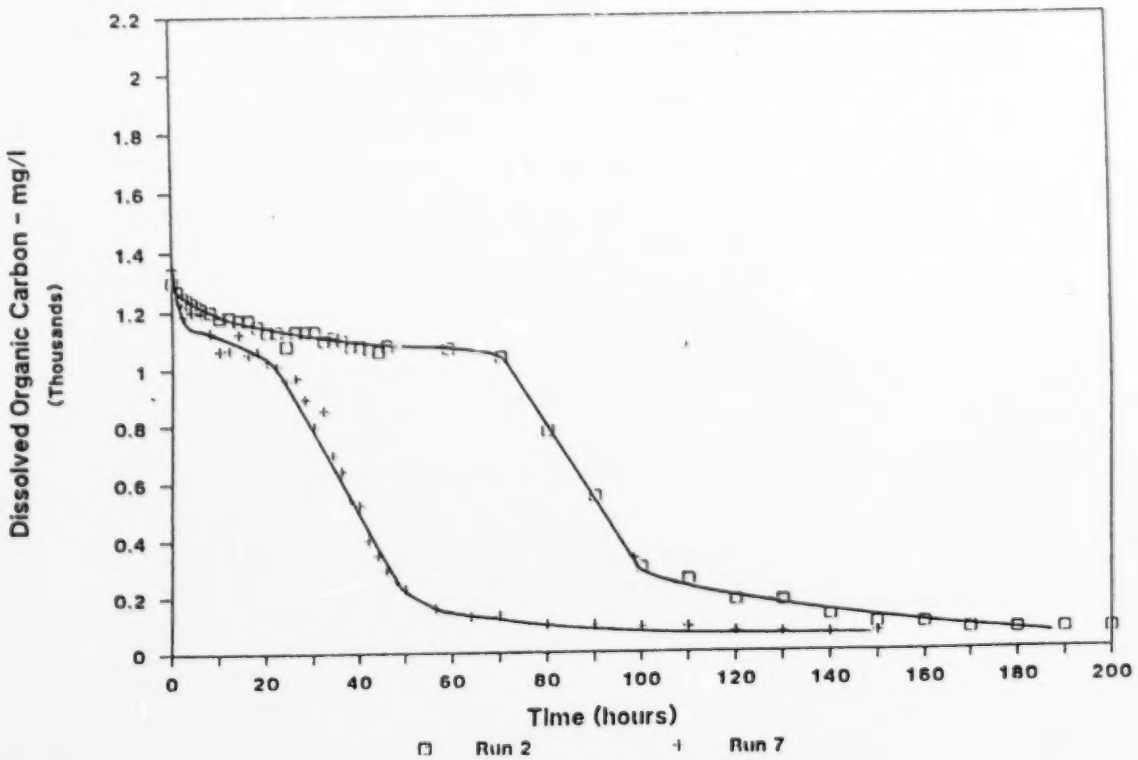

Figure 4. Disappearance of DOC with time experiment 2 and 7.

TABLE 2. GAS ANALYSES OF VOLATILE ORGANICS

Time h	Acetone mg/L	MEK mg/L	Toluene mg/L	Ethyl Benzene mg/L
0	—	—	—	—
0.5	61	320	14	2.1
2.5	500	1900	4.0	4.1
4.5	87	270	<1.2	<1.2
6.5	38	110	<1.2	<1.2

The figures show an initial drop in the DOC concentration. This is attributed to the volatile organics being stripped from solution (see Figure 2, experiment 4). There is evidence of this drop-off in each of the experiments. To verify this assumption, experiment 6 was operated without biomass and the exhaust from the RBC was measured to determine the air flow rates. Samples were withdrawn by inserting a 10 ml syringe in the exhaust line and analyzing for specific organics; acetone methyl ethyl ketone, toluene, and ethyl benzene. The gas analyses data are shown in Table 2. The data show a maximum concentration after 2.5 hours for all compounds, except toluene, followed by a significant drop in concentration at 4.5 hours and a gradual drop at 6.5 hours. The lower concentrations of organics in the gas stream with time is attributed to the lower mol fraction of the volatile organics within the leachate as the material is stripped from solution.

TABLE 3. MATERIAL BALANCE FOR MEK

	Leachate		Gas			Leachate
Time h	MEK conc mg/L	MEK wt g	flow L/h	MEK conc mg/L	MEK wt g	MEK wt* g
0	180	680	130,000	—	—	680
0.5	160	600	130,000	.32	10	670
2.5	110	420	130,000	1.88	280	390
4.5	100	400	130,000	.27	280	110
6.5	55	210	130,000	.11	50	60

* Based on subtracting the mass of MEK removed by stripping from the mass of MEK originally in the liquid.

TABLE 4. RATES OF REACTION AND NUTRIENT RATIOS

Expt.	Reaction Rate gDOC/h	Ratio C/N/P
1	140	100/5.5/<.2
2	82	100/1/<.2
3	350	100/5.5/1.4
4	180	100/1.1/<.2
5	300	100/5/2
7	120	100/6.7/<.2

Note: The C/N/P ratios shown are different from the earlier values given when describing the experimental conditions. The values in this Table reflect the contribution of the primary effluent and the leachate.

TABLE 5. REMOVAL OF POLLUTANTS FROM NEW LYME LEACHATE

	Experiment No. 1 L/PE = 1L/2L			
	L* mg/L	PE mg/L	INF mg/L	Cl EFF mg/L
SBOD	3400	120	1200	<2.0
BOD_T	—	—	1600	—
DOC	2100	100	760	17
TOC	—	—	830	19
SCOD	5900	290	2100	66
COD_T	—	—	2200	69
NH_3-N	8.1	43	32	0.3
TKN-N	14	54	42	2.6
NO_3-N	<1.0	—	1.7	—
PO_4-P	<0.2	2.6	—	<0.2
SS	1200	140	590	170
VSS	380	110	220	110
Volatile PP				
Benzene	0.26	—	—	<0.025
1,1-Dichloroethane	0.22	—	—	<0.013
Chloroform	0.066	—	—	<0.013
Ethylbenzene	0.50	—	—	<0.025
Methylene Chloride	11	—	—	12
Toluene	1.7	—	—	<0.025
Trichloroethylene	0.023	—	—	<0.013
Additional Volatiles				
Cis 1,2-Dichloroethene	3.9	—	—	0.011
Xylenes	0.22	—	—	—
Acetone	13	—	—	0.35
Methyl Ethyl Ketone	65	—	—	1.1
Methyl Isobutyl Ketone	12	—	—	0.49
2-Hexanone	1.0	—	—	—
Additional Acid				
Benzoic Acid	5.9	—	—	—
4-Methyl Phenol	2.9	—	—	—
2-Methyl Hexanoic Acid	2.9	—	—	—
TOX	0.46	—	—	0.77

* L = Leachate
PE = Primary Effluent
INF = Influent to RBC
Cl EFF = Clarifier Effluent
ND = Not Detected
— = Not Analyzed
TOX = Total Organic Halides

TABLE 6. REMOVAL OF POLLUTANTS FROM NEW LYME LEACHATE

	Experiment No. 2, 3, 4 L/PE = 2L/1L				
	L mg/L	PE** mg/L	INF mg/L	Cl EFF mg/L	Sludge mg/L*
SBOD	4800	140	3000	4.4	—
BOD_T	5000	230	3300	8.4	—
DOC	2200	82	1400	19	—
TOC	2200	102	1500	20	—
SCOD	5200	220	3700	50	—
COD_T	5600	370	4100	78	—
NH_3-N	8.0	15	32	2.3	—
TKN-N	14	22	—	4.3	—
NO_3-N	<1	<1	<1	—	—
PO_4-P	<0.2	2	<0.2	2.6	—
SS	920	260	860	56	—
VSS	200	140	210	35	
Volatile PP					
Benzene	0.26	<0.002	—	<0.002	<0.050
1,1-Dichloroethane	0.22	<0.001	—	<0.001	<0.025
Chloroform	0.066	<0.001	—	<0.001	<0.025
Ethylbenzene	0.50	<0.002	—	<0.002	<0.050
Methylene Chloride	11	0.066	—	<0.002	<0.050
Toluene	1.7	<0.002	—	<0.002	3.7
Trichloroethylene	0.023	<0.001	—	<0.001	<0.025
Base Neutral					
Bis(2-Ethylhexyl) Phthalate	—	<0.026	—	<0.0025	0.043
1,2,4-Trichloro Benzene	—	0.51	—	<0.0025	<0.016
Additional Volatiles					
Cis 1,2-Dichloroethene	3.9	—	—	—	—
Xylenes	0.22	—	—	—	—
Acetone	13	—	—	—	—
Methyl Ethyl Ketone	65	—	—	—	—
Methyl Isobutyl Ketone	12	—	—	—	—
2-Hexanone	1.0	—	—	—	—
Additional Acid					
Benzoic Acid	5.9	—	—	—	—
4-Methyl Phenol	2.9	—	—	—	0.47
2-Methyl Hexanoic Acid	2.9	—	—	—	—
Phenol (PP)	—	<0.026	—	<0.0025	0.060
TOX	0.46	—	—	0.14	—
TTO	—	0.51	—	<0.010	4.2

* Sludge Sample accumulated after Experiment 2.
** Primary pollutants from Experiment 3.
TTO = Total Toxic Organics

A material balance was calculated for MEK in the leachate by analyzing the RBC tank contents at specific time intervals. The calculated leachate values shown in Table 3 were obtained by multiplying the gas flow in the exhaust line by the concentration of MEK in the gas stream after various time intervals and subtracting this value from the MEK originally contained in the leachate. The MEK remaining in the batch after 6.5 hours of operation was higher, based on the leachate analysis method as compared to subtracting the MEK accounted for in the gas stream from the MEK originally present in the leachate. However, both methods show continual drop-off of MEK and the gas analyses proves that MEK was stripped from solution. Provisions may be necessary to capture the volatile organics from an RBC to prevent air contamination when treating leachates with an RBC.

After stripping, there was a period with a reduced reaction rate that was attributed to acclimation of the biomass to the leachate (see Figure 2, experiment 4). There was only a slight drop in DOC during this time interval. The acclimation period varied, but it was especially evident in experiments 2 and 7 where the acclimation period lasted for 20 and 40 hours, respectively. The lengthy acclimation period for experiment 2 was attributed to an inadequate biomass. Prior to the start of experiment 2, the biomass was observed to be reddish-brown and spotty with a noticeable decrease in thickness, indicating that considerable sloughing-off of the biomass had occurred. The extended acclimation period for experiment 7 was attributed to the fact that it followed the volatile organics stripping run where the biomass had been removed from the discs. There was therefore no prior acclimation of the biomass to the leachate.

Following the acclimation period, the reaction progressed at a constant rate, as shown in Figure 2, experiment 4 by the disappearance of DOC, with time. The reaction rate varied for each experiment, ranging from a high of 350g DOC converted per hour to a low of 82 grams per hour. The two experimental runs that had rates equal or greater than 300 grams per hour contained adequate levels of both nitrogen and phosphorus, and had an adequate acclimation period from previous runs. It appears that the nutrient addition for experiments 3 and 5 may have contributed to the high organic removal rate. However, additional cause and effect experiments are needed to verify that nutrients may influence the reaction rate. The reaction rates for the six experiments and the ratios of C/N/P are shown in Table 4.

TABLE 7. REMOVAL OF POLLUTANTS FROM NEW LYME LEACHATE

	Experiment No. 5		Sludge	7	
	L mg/L	EFF mg/L	mg/L*	L mg/L	CL EFF mg/L
SBOD	2700	4	—	2000	3.2
BOD_T	3000	6.6	—	2600	21
DOC	2000	17	—	1400	45
TOC	2100	19	—	1400	52
SCOD	5200	33	—	3800	190
COD_T	—	—	—	4000	220
NH_3-N	100	—	—	84	33
TKN-N	110	—	—	92	42
NO_3-N	<1	60	—	<1	21
PO_4-P	—	1.4	—	<0.2	0.4
SS	1400	6600	51000	1100	88
VSS	240	2600	19000	270	58
Volatile PP					
Benzene	0.28	<0.002	<0.010	<0.002	<0.001
Toluene	4.9	<0.002	0.018	4.3	<0.001
Acid PP					
Phenol	—	—	—	1	—
Additional Volatiles					
Cis 1,2-Dichloroethene	0.94	ND	—	—	—
Xylenes	2.8	ND	0.025	1.9	—
Acetone	140	ND	0.012	27	—
Methyl Ethyl Ketone	470	ND	0.021	200	—
Methyl Isobutyl Ketone	—	—	—	46	—
Methyl Disulfide	—	—	—	1	—
Dimethyl Disulfide	—	—	—	1	—
Dimethyl Trisulfide	—	—	—	1.2	—
Additional Acid					
4-Methylphenol	—	—	—	1	—
2 Methylpentanoic Acid	—	—	—	4.6	—
2 Methylhexanoic Acid	—	—	—	10	—
Hexanoic Acid	—	—	—	5.2	—
Nonanoic Acid	—	—	—	3.1	—
Decanoic Acid	—	—	—	2.1	—
TOX	—	1.2	—	—	0.72
TTO	<0.250	<0.010	0.018	5.4	<0.010

* Sludge sample accumulated after Experiment 5.
EFF-Effluent from RBC.
ND = Not Detected.
— = Not Analyzed.

Pollutant Removals

The experiments with New Lyme leachate were analyzed for typical biological parameters and priority pollutants. The removal of gross organics was determined by analyzing the influent and effluent for DOC, SBOD, SCOD, TOC, total BOD ($BOD)_T$, and COD_T. Other biological parameters analyzed included suspended solids (SS) and volatile suspended solids (VSS), as well as the nutrient chemicals, both the nitrogen series, and phosphorus [7]. The results show good removals of organics, except for experiment 7, which operated without benefit of prior acclimation runs. The clarified effluent had SBOD levels well below the normal discharge limits for a municipal treated secondary effluent (30 mg/L). The results also indicated that nitrification had occurred by the drop in ammonia-nitrogen.

The priority pollutant levels for untreated New Lyme leachate were compared with the effluents from the RBC after each experiment and, on occasion, were compared with the sludge from the clarifier. Several volatile organics that were present in measurable quantities were identified during the priority pollutant analyses. Their removals were occasionally followed during the RBC experiments.

The summary charts shown in Tables 5, 6, and 7 list the analytical data for the experiments with New Lyme leachate. The data for the biological parameters in experiments 2, 3, and 4 were averaged, since they were all run at the same leachate/PE ratio. These results indicate that the removal of the pollutant by the RBC was effective for all the contaminants. The gross organics as represented by DOC, SBOD, and SCOD were reduced to levels approaching a treated municipal secondary effluent. Only in the effluent from experiment 1 was a priority pollutant, methylene chloride, detected. Otherwise, the biological treatment was effective for converting the priority pollutants into innocuous products.

Sludge samples were analyzed following experiments 2 and 5. Toluene was the only priority pollutant identified both times as present in the sludge. It was not determined whether the toluene was present in the liquid or solid phase. However, since toluene was not detected in the effluent, it is assumed that the toluene was associated with the solids in the sludge.

CONCLUSIONS

The study on treating the New Lyme leachate with an RBC showed effective removals at satisfactory reaction

rates. The RBC was an effective treatment process for reducing the organics in New Lyme leachate. Priority pollutants were converted and/or stripped from the leachate during treatment. The effluent quality is equivalent to a secondary treated effluent from a municipal wastewater treatment plant. Nutrient addition, at ratio of C/N/P of 100/5/2, showed evidence of favorably influencing the reaction rate. Volatile organics were stripped from the leachate by the RBC action when operated in a batch mode. Finally, the RBC experienced a period of inactivity near start-up, which is assumed to be caused by the need for the biomass to acclimate to the leachate.

The RBC offers a high degree of treatment for processing leachates from a hazardous waste site. Additional research is needed to determine the degree of organic stripping while the biodegradation reaction is occurring, and to validate the rapid reaction rate kinetics when the nutrients are controlled at their theoretical levels.

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